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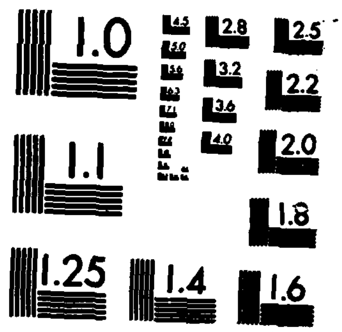

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FABRICATE, CALIBRATE and TEST A DOSIMETER FOR INTEGRATION INTO THE CRRES SATELLITE

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AD-A150 683

October 1983

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A space-radiation dosimeter is being fabricated, calibrated, tested, and integrated into the CRRES satellite. This Dosimeter is essentially identical to that previously designed, fabricated, calibrated, tested and integrated into the DMSP F7 satellite. These dosimeters are primarily designed to measure the dose from electrons of greater than 1 MeV to greater than 10 MeV in four channels. Each channel has a different thickness aluminum dome

20. Abstract (Continued)

The solid state detector outputs are processed to provide the dose from electrons (low energy loss), the dose from protons (high energy loss), the flux of electrons, the flux of protons, and the rate of high energy loss nuclear star events. The dosimeter also has a calibration mode in which the alpha particles from a weak source behind each detector are used to check for total detector depletion and proper operation of the electronics.

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1. INTRODUCTION

The increasing use of complex solid state electronic devices in the space radiation environment makes it important to have reliable data on the radiation doses these devices will receive behind various thicknesses of shielding. As part of the effort to obtain this data a Dosimeter was designed, fabricated, calibrated, and integrated into the payload of a Defense Meteorological Satellite Program (DMSP) satellite by Panametrics, Inc., for the Air Force Geophysics Laboratory, under contract number F19628-78-C-0247. The current contract, F19628-82-C-0090, is for the fabrication and calibration of a second, essentially identical, Dosimeter and its integration into the Combined Release and Radiation Effects Satellite (CRRES). These Dosimeters measure the accumulated radiation dose in silicon solid state detectors behind four different thicknesses of aluminum shielding.

The objectives of the current contract can be summarized as follows:

a. Participate in the integration and launch tests of the F7 DMSP satellite in order to determine proper interfacing, of the DOSIMETER, with other satellite components and proper operation prior to, and immediately after launch.

b. Study the DMSP DOSIMETER calibration and early flight data to determine the optimum method of producing omnidirectional spectra from the electron and proton data and determine the dose calibrations for small, large and very large energy deposition levels.

c. Fabricate, test, calibrate and deliver a radiation DOSIMETER, essentially identical to the DMSP DOSIMETER, for integration into the CRRES satellite.

d. Participate in the integration and launch tests of the CRRES satellite in order to determine proper interfacing, of the DOSIMETER, with other satellite components and proper operation prior to, and immediately after launch.

e. Analyze calibration and early flight data of the CRRES DOSIMETER to determine the performance of the dosimeter in space flight and the quality of flight data.

This report covers the work carried out during the first year (1 September 1982 to 31 August 1982). A brief description of the Dosimeters, and a summary of their specifications, are given in Section 2. Section 2.1 deals specifically with the DMSP Dosimeter while Section 2.2 deals with the CRRES Dosimeter. The progress to date is summarized in Section 3. Section 3.1 covers the DMSP integration and launch support (item a, above) as well as the DMSP calibration and flight data analysis (item b) while Section 3.2 covers the CRRES Dosimeter fabrication,

testing and calibration (item c) as well as the CRRES integration and launch support (item d). No effort has yet been expended on item 3, since it cannot begin until item c is completed.

2. DOSIMETER DESCRIPTIONS AND SPECIFICATIONS

2.1 Description and Specifications of the DMSP Dosimeter

The DMSP Dosimeter was designed, fabricated, tested and calibrated by Panametrics, Inc., for the Air Force Geophysics Laboratory, under contract number F19628-78-C-0247. This instrument's specifications are outlined in Table 2.1. It should be noted that the unit was specifically designed to interface with the DMSP spacecraft and its Operational Linescan System (OLS). The DC to DC converter design, in particular, took advantage of the closely regulated DMSP power buss (28.0 $\pm$ 0.5 VDC) which eliminates the requirement for further line voltage regulation and results in reduced power consumption, weight and volume. The data registers are also optimally scaled for the approximate circular 800 km DMSP orbit. A detailed description of the DMSP Dosimeter is presented in Ref. 2.1. The design is, of course, adaptable to other spacecraft and/or orbits.

An isometric view of the DMSP Dosimeter is shown in Fig. 2.1. The 4 domes house the solid state detectors. The dome thickness increases with the size, resulting in four different incident particle energy thresholds. The instrument interfaces to the DMSP spacecraft through P1 and to the OLS through P2. J12 is a test connector which is capped during flight. A cutaway isometric view, showing the various printed circuit boards and the details of one detector, is given in Fig. 2.2. The four charge sensitive preamplifier test input connectors, shown in Fig. 2.2, are also capped for flight.

The Dosimeter separates the total radiation dose into that from electrons (50 keV to 1 MeV energy deposits) and protons (1 to 10 MeV energy deposits). The four aluminum shields provide energy thresholds (range thickness values) of 1, 2.5, 5, and 10 MeV for electrons, and 20, 35, 51, and 75 MeV for protons. The primary measurement, and that most accurately calibrated, is the accumulated dose. Omnidirectional electron and proton fluxes are also measured, and data on the detailed response of each channel to energy and angle for electrons and protons have been obtained. There is also a high energy loss event channel which counts the rare nuclear star events caused by high energy protons, and the low flux of high energy high-Z cosmic rays. Information on these high energy loss events is important, since they can cause logic upsets or memory bit loss in some types of low power micro-circuits.

The DMSP Dosimeter was extensively calibrated by use of protons from the Harvard Cyclotron, and electrons from the AFGL Linac. The 160 MeV proton beam at the Harvard cyclotron was

Table 2.1

Specifications for the DMSP Dosimeter

Sensors	4 Planar silicon S.S.D. with aluminum shields
Field of View	2 π Steradians
Data Fields	3 deposited energy ranges and 2 dose energy ranges per sensor, resulting in 5 data fields: 1 Electron Dose 1 Electron Flux 1 Proton Dose 1 Proton Flux 1 Nuclear Star Flux
Output Format	36 Bits serial, read out once per second. Each readout is internally multiplexed and must be interpreted in the context of a 64 readout data frame.
Command Requirements	On/Off, Reset, and Calibrate
Size	8" H x 4.5" W x 5.5" D excluding Domes, Connectors, and Mounting Tabs
Weight	10 lbs
Power	7 W @ 28 V $\pm$ 0.5 V DC
Temperature Range	-10^{o}C to 40^{o}C
Max Accumulated Dose before recycling	$\simeq 10^4$ rads (Si) Electrons $\simeq 10^3$ rads (Si) Protons
Max Flux before overflow	$\simeq 10^6$ Electrons/(cm^2-sec) above 1 Mev $\simeq 10^4$ Protons/(cm^2-sec) above 20 MeV
Effective Area (For omnidirectional flux)	0.013 cm^2 (Dome 1), 0.25 cm^2 (Dome 2, 3, and 4)

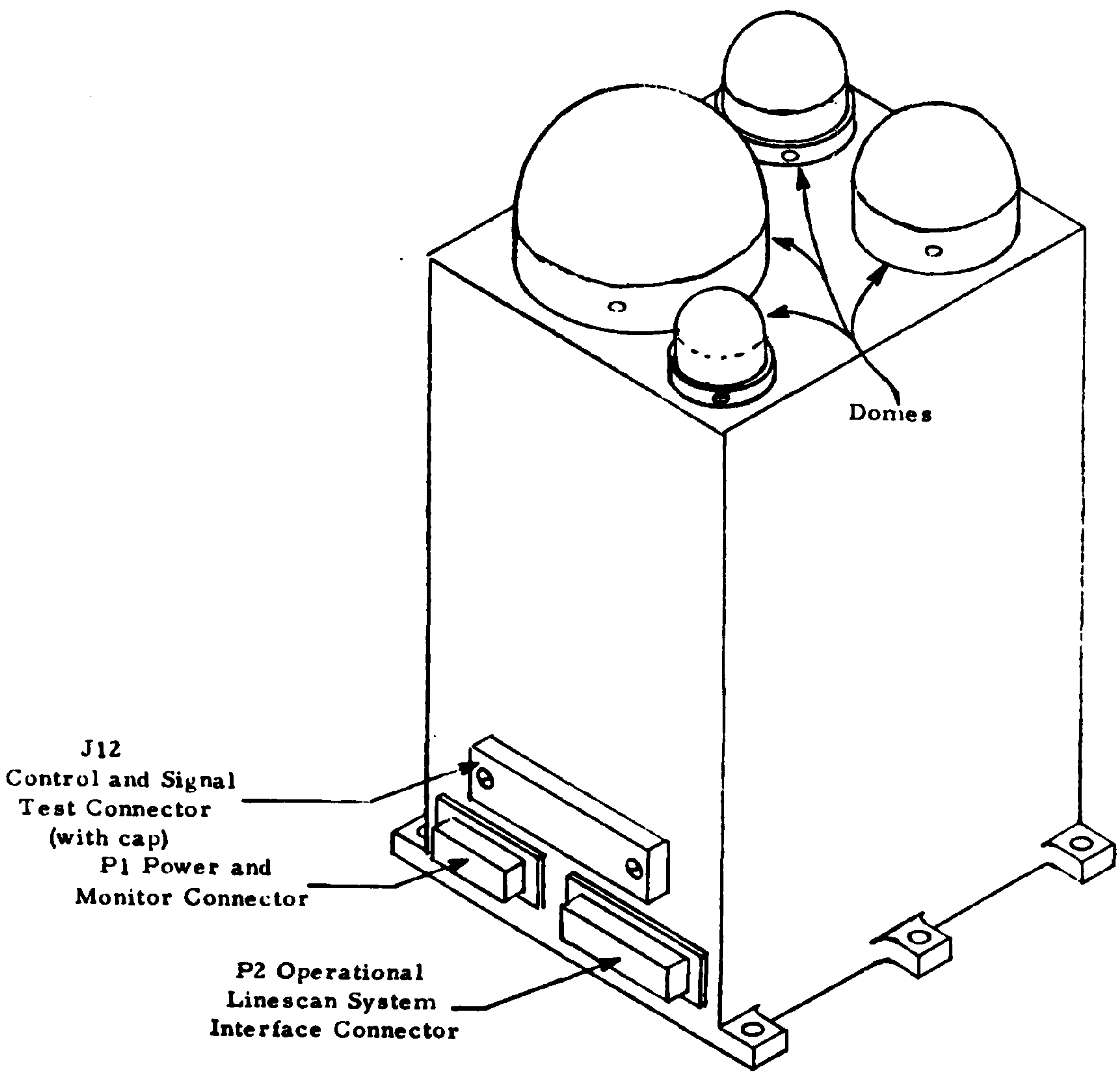

Fig. 2.1 Isometric View of the DMSP Dosimeter

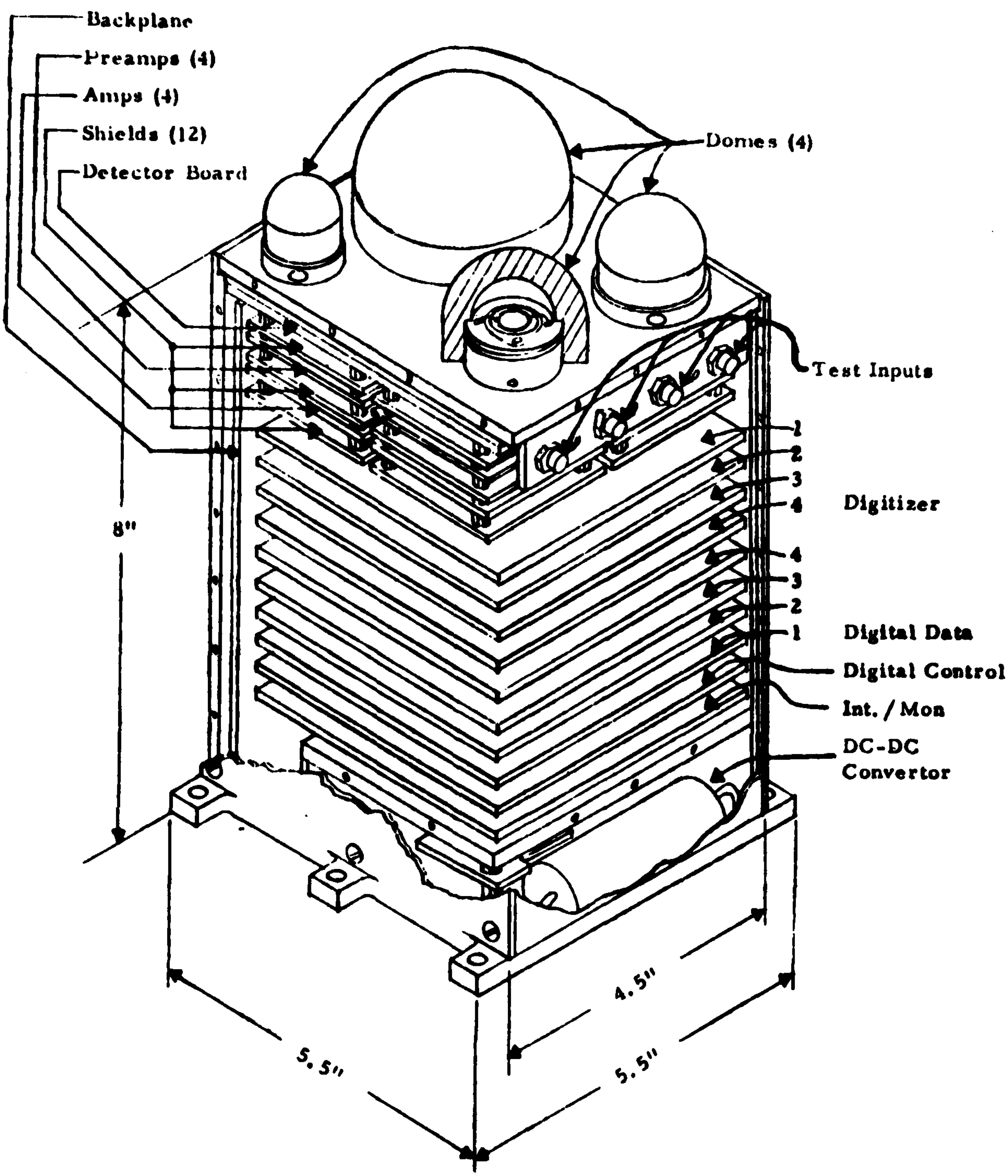

Fig. 2.2 Cutaway Isometric View of the DMSP Dosimeter

passed through two beam-spreading absorbers to provide a maximum energy of 144 MeV at the Dosimeter. Additional absorbers were used to reduce the energy to as low as 17 MeV. Data were taken for incident directions (relative to the Dome plane normal) of from 0° to 180° (rear entry). The electron data taken at the AFGL linac covered the range of 0.9 to 18.4 MeV. The nominal electron energies were calibrated against known gamma-ray energies with a 1 inch thick BGO crystal, so the corrected energies should be accurate to better than 5%. The Dosimeter was also calibrated extensively using gamma-ray and beta sources, with this being the primary method of calibrating the dose channel responses. The electron and proton beam calibrations are primarily to verify proper unit operation, and to calibrate the flux channels in terms of the incident particle fluxes.

The final parameters for the four channels of the DMSP dosimeter are given in Table 2.2. These values are based on the final dose prescaler values and the calibrated detector responses. The electron channels are based on detector energy losses of 50 keV to 1 MeV, and the proton channels on 1 MeV to 10 MeV. In the calibration mode the electron channel becomes a lower loss range of 1 to 3 MeV and the proton channel an upper loss range of 3 to 10 MeV. This mode is used to check total depletion of the detectors by looking at the alpha source which irradiates the rear of the detectors.

The DMSP Dosimeter underwent a complete acceptance test sequence, in accord with a Test and Acceptance Plan approved by AFGL. Vibration testing was carried out at the AFGL test facility. Thermal and vacuum testing was done in house at Panametrics. Initial spacecraft integration tests took place at the Westinghouse (the OLS contractor) facility in Baltimore, Maryland and the Dosimeter was shipped to RCA Astroelectronics Division (the spacecraft contractor) on June 2, 1981 for integration into the DMSP F-7 spacecraft.

2.2 Description and Specifications of the CRRES Dosimeter

The specifications for the CRRES Dosimeter which is being fabricated, tested and calibrated by Panametrics, Inc. for the Air Force Geophysics Laboratory, are outlined in Table 2.3. These specifications are identical to those of the DMSP Dosimeter except for the power buss regulation which is now 28.0 $\pm$ 4 VDC, as opposed to the 28.0 $\pm$ 0.5 VDC DMSP power buss. This necessitates the addition of a line voltage regulator, and it results in a slight increase in the instrument's volume, weight and power requirements - all of which are indicated in Table 2.3.

An isometric view of the CRRES Dosimeter is shown in Figure 2.3. The power buss regulator is contained in the 4" x 4" x 1" protrusion on the side of the instrument.

Table 2.2

Final Parameters for the DMSP Dosimeter

Item	Ch 1 Value	Ch 2 Value	Ch 3 Value	Ch4 Value
Al Shield (g/cm^2)	0.55	1.55	3.05	5.91
Electron Threshold (MeV)#	1.0	2.5	5.0	10.
Proton Threshold (MeV)#	20	35	51	75
Star Threshold (MeV)#	40	40	75	40
Detector Area (cm^2)	0.051	1.00	1.00	1.00
Max elect. flux (cm^{-2} sec^{-1})*	2.41×10^6	1.23×10^5	1.23×10^5	1.23×10^5
Max proton flux (cm^{-2} sec^{-1})*	1.95×10^4	922	922	922
Elect. dose prescaler	8192	16384	4096	4096
Proton dose prescaler	64	1024	256	256
Max. elect. dose (RADS)**	1.27×10^4	1.29×10^3	323	323
Max. proton dose (RADS)**	990	808	202	202
Electron calibration constant (RADS/output dose count)	1.78×10^{-3}	1.81×10^{-4}	4.30×10^{-5}	4.85×10^{-5}
Proton calibration constant (RADS/output dose count)	1.36×10^{-4}	1.11×10^{-4}	2.90×10^{-5}	2.92×10^{-5}

*Flux value above which the flux count will overflow. Only the flux readouts are affected, as dose is still accumulated correctly.

**Dose at which the counters overflow and recycle to zero. Dose accumulation continues correctly.

#The electron and proton thresholds are the nominal particle energy to just penetrate the dome shields; the star thresholds refer to energy deposits in the detectors.

Table 2.3

Specifications for the CRRES Dosimeter

Sensors	4 Planar silicon S.S.D. with aluminum shields
Field of View	2π Steradians
Data Fields	3 deposited energy ranges and 2 dose energy ranges per sensor, resulting in 5 data fields: 1 Electron Dose 1 Electron Flux 1 Proton Dose 1 Proton Flux 1 Nuclear Star Flux
Output Format	36 Bits serial, read out once per second. Each readout is internally multiplexed and must be interpreted in the context of a 64 readout data frame.
Command Requirements	On/Off, Reset, and Calibrate
Size	8" H x 4.5" W x 6.5" D excluding Domes, Connectors, and Mounting Tabs
Weight	10.6 lbs
Power	7.5 W @ 28 V $\pm$ 4.0 V DC
Temperature Range	-10°C to 40°C
Max Accumulated Dose before recycling	$\simeq 10^4$ rads (Si) Electrons $\simeq 10^3$ rads (Si) Protons
Max Flux before overflow	$\simeq 10^6$ Electrons/(cm^2-sec) above 1 MeV $\simeq 10^4$ Protons/(cm^2-sec) above 20 MeV
Effective Area (For omnidirectional flux)	0.013 cm^2 (Dome 1), 0.25 cm^2 (Dome 2, 3, and 4)

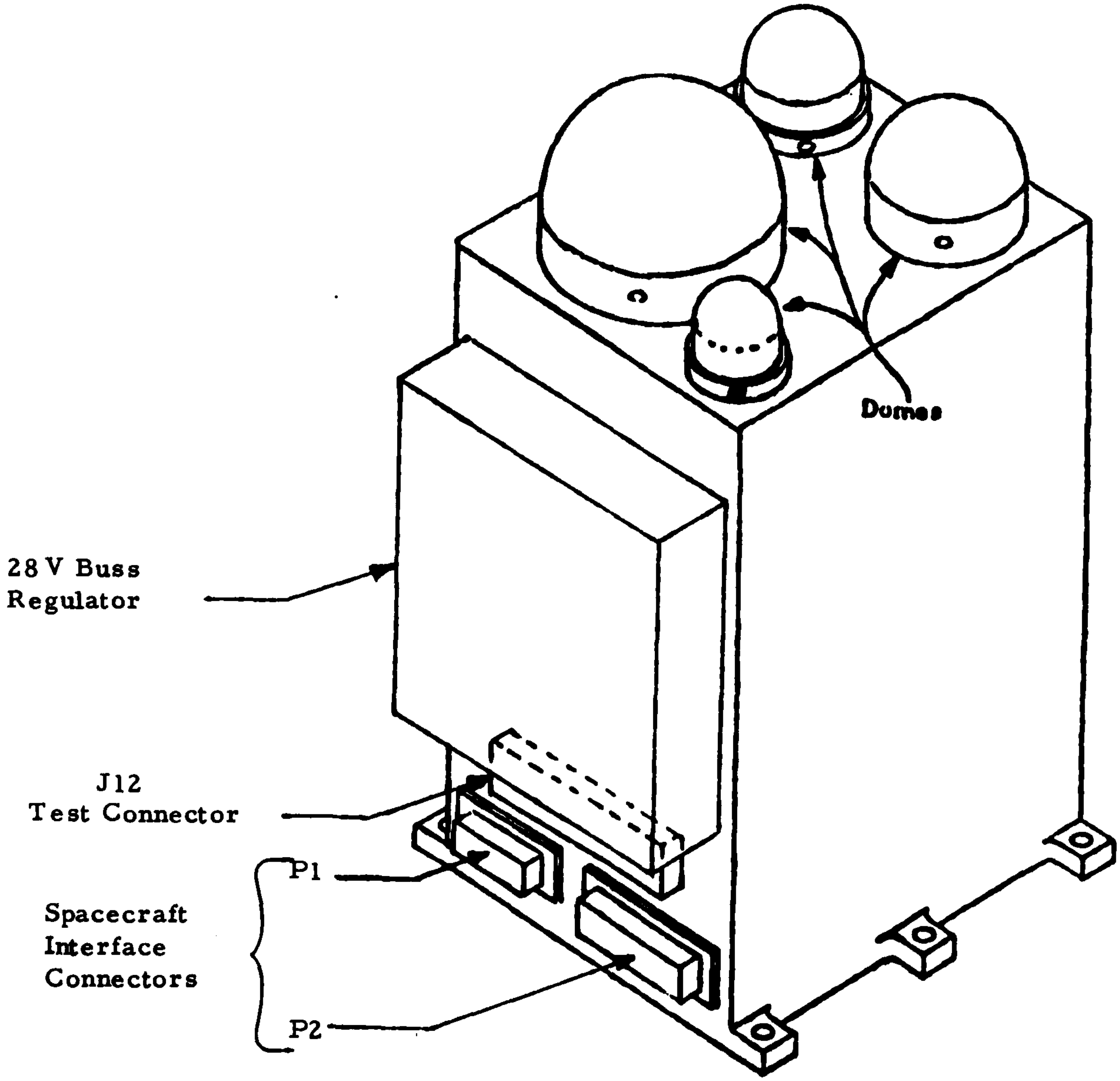

Fig. 2.3 Isometric View of the CRRES Dosimeter

3. PROGRESS TO DATE

3.1 DMSP Dosimeter

3.1.1 Integration and Launch Support

Initial spacecraft integration testing of the DMSP Dosimeter took place at the Westinghouse (the OLS contractor) facility in Baltimore, Maryland and the Dosimeter was shipped to RCA Astroelectronics Division (the spacecraft contractor) on June 2, 1981 for integration into the DMSP F-7 spacecraft. Note that the DMSP instruments are referred to as "special sensors" and the Dosimeter is designated the "SSJ*" special sensor.

Several sets of SSJ* DMSP Integration test data were received from RCA during the last 10 months of 1982. These are as follows:

a) First System Test
b) 0°C Thermal Test
c) Pre Thermal - Vacuum #1
d) EMI/RFI
e) Pre Thermal - Vacuum and EMI
f) Pre Thermal Vacuum - Go/No-Go
g) Thermal Vacuum - Orbit Days 1 through 11 (one set of test data for each day)
h) Post Thermal Vacuum - Go/No-Go

All of these test data were thoroughly reviewed relative to accurate baseline values recorded at Panametrics prior to delivery. All but two of the data sets show no statistically significant change from baseline values. The pre-thermal-vacuum Go/No-Go test data indicate a channel 3 proton dose which is too low during the first portion of the test (~2500 sec). The dose count is 30-40 counts too low at ~2500 sec. Subsequently, the channel 3 proton dose accumulation rate is correct, but shows a 30-40 count offset. A similar anomaly appears in the post thermal-vacuum Go/No Go test data, where the indicated channel 3 proton dose is again too low during the first portion of the test (~4500 sec. this time).

A detailed investigation, including the removal of the instrument from the spacecraft and its return to Panametrics for testing, was carried out. The final conclusion of said investigation was that there is nothing wrong with the SSJ* - it was simply turned on at too low a temperature. The details of this investigation were reported to AFGL.

The SSJ* was returned to RCA on March 3, 1983. Four additional sets of SSJ* DMSP integration test data have been received since that time. These have been thoroughly reviewed relative to accurate baseline values recorded at Panametrics prior to delivery and show no statistically significant change from these baselines. Integration and testing of the DMSP F-7 spacecraft is essentially complete and launch should occur shortly.

3.1.2 Calibration and Flight Data Analysis

The DMSP F-7 spacecraft was not launched during the time period covered by this report, so no flight data could be analyzed. A detailed list of the proton and electron calibration data were given in Ref. 2.3, but these data have not yet been analyzed in detail. The calibration data will be analyzed to provide geometrical factors for the flux channels of the SSJ* dosimeter for the DMSP F-7 satellite.

The baseline Normal Mode and Calibration Mode data from the alpha particle calibration sources behind each detector are given in Table 3.1. These data were used for all the pre-flight checks of the SSJ* during integration and testing of the DMSP F-7 spacecraft. The values for vacuum operation are slightly different from those for air operation, so two data sets are given. These data will be used to check the SSJ* dosimeter operation in orbit after turn-on.

Table 3.1

SSJ* Dosimeter on DMSP F-7 Alpha Particle Source Calibration Data

Output counts per readout (4 seconds) in air
Normal mode/Calibration mode

Item	Dome 1	Dome 2	Dome 3	Dome 4
P/U Flux	4.69/1.91	5.37/1.86	6.07/2.58	5.22/2.07
E/L Flux	0.46/2.29	1.13/3.58	1.00/3.68	0.78/3.17
P/U Dose	3.31-1/4.72-2	2.31-2/2.73-3	1.07-1/1.66-2	9.29-2/1.36-2
E/L Dose	3.71-4/3.41-3	3.91-4/2.60-3	1.53-3/1.02-2	6.71-4/9.32-3

Output counts per readout (4 seconds) in vacuum
Normal mode/Calibration mode

Item	Dome 1	Dome 2	Dome 3	Dome 4
P/U Flux	4.98/2.26	5.64/2.35	6.14/3.07	5.31/2.60
E/L Flux	0.34/2.28	0.85/3.24	0.78/3.16	0.69/2.64
P/U Dose	3.33-1/5.08-2	2.48-2/3.14-3	1.15-1/1.72-2	1.07-1/1.38-2
E/L Dose	2.67-4/3.66-3	2.86-4/2.96-3	1.03-3/9.90-3	7.52-4/7.98-3

Note: $N - n \equiv N \times 10^{-n}$

3.2 CRRES Dosimeter

3.2.1 Fabrication, Testing and Calibration

Fabrication and testing of the CRRES Dosimeter is nearing completion. All of the printed circuits boards, machined parts and components are now in house. The Dosimeter contains 23 printed circuit boards. The charge sensitive preamplifiers (4 identical boards) have been completely fabricated and tested, as have the shaping and star amplifiers (again 4 identical boards). These 8 boards have been assembled to their mother board, and that sub-assembly has been tested. The 3 printed circuit boards comprising the DC to DC converter have been fabricated and that sub-assembly has been completed and tested. The 4 identical digital data boards have been completely fabricated and tested while the 4 identical digitizer boards have been completely fabricated and are currently being tested. The remaining 3 boards (digital control, interface/monitor and backplane) have been completely fabricated and will be tested following the digitizers.

3.2.2 Integration and Launch Support

An experimenter's meeting, which was attended by Panametrics' P. Morel, was held at Ball Aerospace Systems Division on May 12-13, 1983. The first day of this meeting was devoted to Ball's presentation of an abbreviated version of their "Progress Requirement Reviews" which they had previously presented to NASA and the Air Force at Marshall Space Flight Center. The second day was devoted to splinter meetings in which each experimenter reviewed, with Ball, their Interface Requirements Document. Appropriate modifications, identified at that time, were to be incorporated in these documents by Ball.

Ball requested that all experimenters provide schematics of their interface circuits (to the first active component) and box materials and thicknesses. This information was transmitted to Ball on May 24, 1983, by letter, with a copy to AFGL.

A meeting was held at AFGL on August 30, 1983 to again discuss the Interface Requirements Document (IRD). Panametrics' P. Morel and J. Hunerwadel were in attendance, as was Ball Aerospace's Carl Holmes. The IRD was again completely reviewed at this meeting.

Ball Aerospace requested that all CRRES experimenters define their long-term storage requirements and preferred conditions. This information was transimitted to AFGL's D. Hardy, by letter, on June 17, 1983.

Ball also requested that all CRRES experimenters define various special requirements. This information was transmitted to AFGL's D. Hardy, by letter, on July 22, 1983.

REFERENCES

2.1 B. Sellers, R. Kelliher, F. A. Hanser, and P. R. Morel, "Design, Fabrication, Calibration, Testing and Satellite Integration of a Space-Radiation Dosimeter," report AFGL-TR 81-0354 AD A113085, (December 1981). Final Report for Contract No. F19628-78-C-0247.

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